Determination of asset prices in the Bank of Japan Macroeconometric Model[1]

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Introduction

The purpose of this paper is twofold: (i) to describe the asset price equations in the Bank of Japan Macroeconometric Model (hereafter BOJMOD); (ii) to evaluate these equations by focusing on the role of market participants' expectations in the determination of asset prices.

The paper is organised as follows. Section 1 is an introduction to the asset price equations of the BOJMOD. It provides a brief description of the determination of long-term interest rates, foreign exchange rates and stock prices. Section 2 will study the dynamic property of the BOJMOD's asset price equations by computing the responses of asset prices to various types of shock. To overcome the Lucas-critique with regard to simulation analysis based on macroeconometric models, this section will adopt the methodology proposed by Sargent (1977), Sargent and Sims (1977) and Mishkin (1979). Section 3 evaluates the asset price determination mechanism of the BOJMOD. Our particular interest is in whether the backward-looking expectations adopted in the BOJMOD is appropriate to describe the way market participants' expectations are formed in Tokyo markets. For this purpose, we will compute the response assuming that asset pricing is based on forward-looking expectations and compare this "theoretical" response to that obtained in Section 2. The final section concludes the paper.

1. Asset price equations of the BOJMOD

1.1 Long-term interest rate

The long-term interest rate equation is based on the expectation hypothesis of the term structure of interest rates, which is represented by the second term of the equation in Table 1. The interest rate on a long-term bond equals an average of short term interest rates that market participants expect over the life of the long-term bond; i.e.,

$$i_t = (1-\beta)\, E_t\left(i_t^s + \beta i_{t+1}^s + \beta^2 i_{t+2}^s + \beta^3 i_{t+3}^s + \cdots\right) \tag{1}$$

where i and i^s stand for long-term and short-term nominal interest rate, respectively, βrepresents the discount factor and E stands for the expectations operator.

An important issue is how expectations of future short rates are formed. In the BOJMOD, the assumption of adaptive expectations is adopted and, reflecting this, the lagged values of CD rates, denoted by RCD, are included on the right-hand side of the equation in Table 1. The parameters corresponding to them are estimated by the Shiller lag procedure.

1 The original version of this paper was presented at the BIS meeting of central bank model builders. The authors would like to thank Mr. R. McCauley (BIS) and other participants of the meeting for helpful comments. Remaining errors are of course ours. The view expressed in this paper are those of the authors and do not necessarily reflect those of the Bank of Japan.

Table 1
Long-term interest rate equation

$$\begin{aligned}\ln(RBND_t) &= \alpha_0 + \sum_{j=0}^{3}\alpha_{1_j}\ln(RCD_{t-j}) + \alpha_2(GDS_t/GDPN_1) + \alpha_3 DEL(1,OCR_t)\\ &+\alpha_4\left(\ln\left(\left(USBND_t + SUM(0.3,GR(4,PGDP_t) - GR(4,USP_t)/4\right)\right)\right)\\ &+\alpha_5 SUM(0.2,GR(1,IBDR_t))/3\end{aligned}$$

α_0	α_{1j}	α_2	α_3	α_4	α_5	$S.E.$	$\bar{R}^2$	$D.W.$	*Sample*
0.019	$\alpha_{1,0}$ = 0.261 (8.98)	0.013	0.001	0.178	0.061	0.005	0.84	0.85	82.3
(3.81)	$\alpha_{1,1}$ = 0.174 (9.07)	(1.92)	(0.96)	(2.54)	(2.89)				94.1
	$\alpha_{1,2}$ = 0.087 (8.69)								
	$\alpha_{1,3}$ = 0.000 (0.10)								
	$\sum\alpha_{1_j}$ = 0.522								

Note: Numbers in parentheses are t-statistics. α_{1j} (j=0,1,2,3) are estimated by the Shiller lag procedure.
Interest rates in percentages (i) are entered as $1 + i / 100$ and inflation rates in percentages (j) as $1 + j / 100$.
$DEL(\cdot,\cdot)$, $GR(\cdot,\cdot)$, and $SUM(\cdot,\cdot,\cdot)$ are defined as:

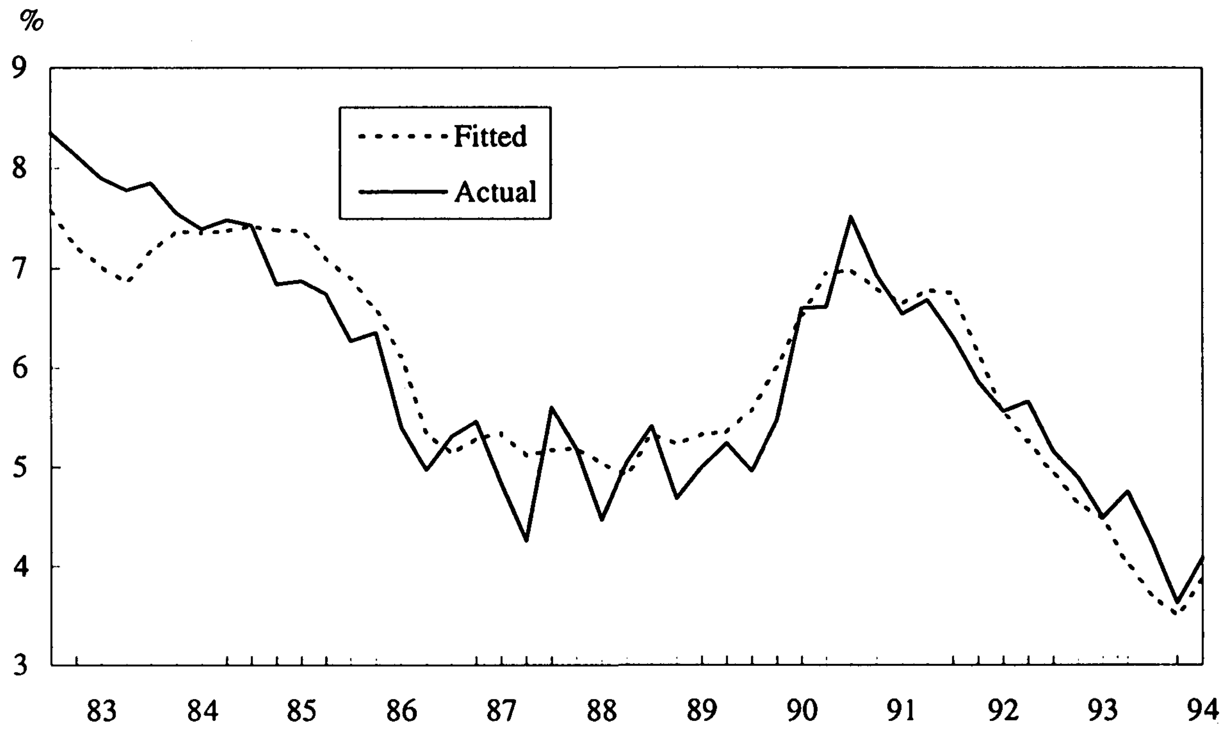
$$DEL(n,X) \equiv X_t - X_{t-n};\quad GR(n,X) \equiv X_t - X_{t-n} - 1;\quad SUM(n,m,X) \equiv \sum_{i=n}^{m} X_{t-n}.$$

RBND	Japanese long-term government bond yield.
RCD	Average interest rate on certificates of deposit.
GDS	Government debt, proxied by accumulated annual budget deficits, in billions of yen.
GDPN	Nominal GDP, in billions of yen.
OCR	Index of capacity utilisation of manufacturing industries, 1990=100.
USBND	U.S. government bond yield. 30-year constant maturities.
PGDP	Japanese GDP deflator, 1985=100.
USP	US GDP deflator, 1987=100.
IBDR	Nominal yen-dollar exchange rate.

The other terms of the equation are interpreted as follows: the third term, the ratio of government debt to nominal GDP, represents the supply side of the long-term bond markets; the fourth term, the difference in the capacity utilisation index, is a proxy for the expectation of inflation; the fifth term represents interest rate arbitrage with U.S. long-term interest rates; the sixth term captures the expected change in the nominal exchange rate.

The performance of the equation is shown in Figure 1.

Figure 1
Long-term interest rate: actual and fitted



1.2 Yen-dollar exchange rate

The exchange rate equation is a variation of the so called portfolio-balance models. To make the explanation simpler, let us start with uncovered interest parity:

$$s_t = E_t(s_{t+1}) - (i_t - i_t*) \tag{2}$$

where s is the logarithm of the nominal exchange rate (yen/dollar) and superscript * stands for foreign variables. A simple modification of (2) yields:

$$q_t = E_t(q_{t+1}) - (r_t - r_t*) \tag{3}$$

where q is the logarithm of the real exchange rate and r represents the real interest rate.

It is assumed that expectations of the real exchange rate at t+1 are formed as:

$$E_t(q_{t+1}) = \mu f_t + (1-\mu) q_t \tag{4}$$

where f_t is the factor representing fundamentals and μ is a parameter satisfying $\mu \in [0,1]$. In words, market participants believe that the real exchange rate approaches the fundamental value at the adjustment speed of μ. Note that market participants' expectations are backward-looking.

Substituting (4) into (3), we get:

$$q_t = f_t - \mu^{-1}(r_t - r_t{*}) \tag{5}$$

This is the basis for the specification listed in Table 2, although the precise specification adopted here differs from equation (5) in the following respects. First, the factor representing fundamentals, f_t, is assumed to be invariant over time. This is based on the idea that the nominal exchange rate tends to converge to the purchasing power parity and, therefore, the real exchange rate converges to a constant value. The constant term of the equation represents the constant value to which the real exchange rate converges. Second, the risk premium associated with exchange rate risks is included as the third term of the equation. Based on the idea that the risk premium would increase with the Japanese private sector's net external asset denominated in dollars, the cumulative current account surplus of Japan, denoted by RPJ, is included on the right-hand side of the equation.[2,3] Also, following the argument of Fukao (1983, 1987) that the yen/dollar rate tends to comove with the

Table 2
Yen-dollar exchange rate

$$\ln(RDR_t) = \alpha_0 + \alpha_1 (RBNDR_t - USBNDR10_t)/100 + \alpha_2 (0.0030RPJ_t + 0.0017RPE_t)/IT1_t$$

α_0	α_1	α_2	*S.E.*	$\bar{R}^2$	*D.W.*	*Sample*
4.461 (309.7)	–2.923 (–4.62)	–1.373 (–15.55)	0.091	0.79	0.44	76.2 93.4

Note: Numbers in parentheses are t-statistics.

RDR Real yen-dollar exchange rate index, 1985=100. Spot rates on the Tokyo interbank market deflated by GDP deflators of the United States and Japan.

RBNDR Japanese real long-term interest rate. Defined as the Japanese government bond yield minus the annual growth rate of the Japanese GDP deflators.

USBNDR10 US real long-term interest rate. Defined as the US government bond yield minus the annual growth rate of the US GDP deflator.

RPJ Cumulative current account surplus of Japan minus direct investments, in millions of dollars and starting in 1974Q1.

RPE Cumulative current account surplus minus direct investments of Germany, France, Italy and the Netherlands, in millions of dollars and starting in 1974Q1.

IT1 Index of nominal GDP of Japan, the United States, Germany, France, Italy and the United Kingdom, 1975Q1=100.

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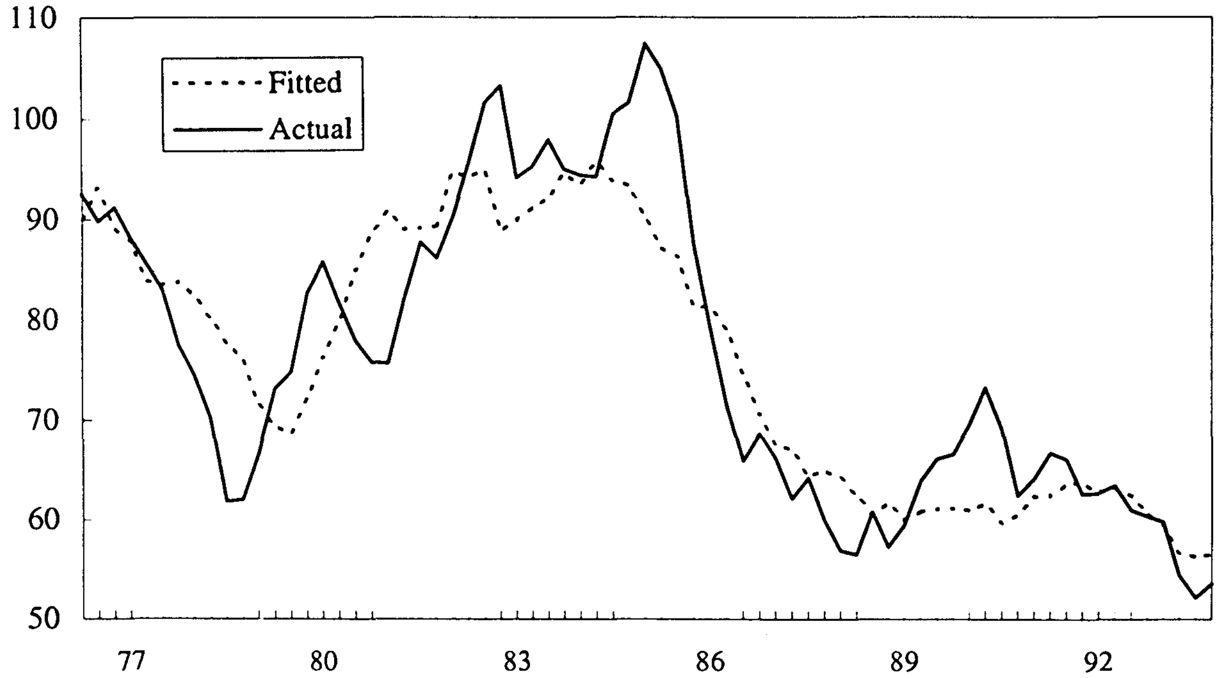
2 The net external position of the private sector includes direct investments. These, however, should be subtracted because they are irrelevant to the risk premium. Taking this into consideration, RPJ in Table 2 is defined as the cumulative current account surplus minus direct investments. The same applies to RPE.

3 It is assumed here that the cumulative current balance could be used as a proxy for the private sector's net external asset. One might argue that this assumption is too strong because (i) a non-negligible part of the cumulative current balance is owned by the public sector, including the government and the central bank, and (ii) the investment behaviour of the public sector could differ from that of the private sector. We, in part, agree to this argument, but still believe that the assumption could be justified in some cases. For example, the assumption is justified in the Ricardian world where the private sector "internalises" the budge constraint of the public sector. Also, the intervention policy of the public sector is sometimes characterised by profit maximisation, particularly in small countries in Asia and Europe. If this is the case, it would be safe to use the cumulative current balance as a proxy for the private sector's external assets. See Fukao (1987) for more on this issue.

DM/dollar rate, the cumulative current account surplus of the major European countries, denoted by RPE, is included.[4, 5]

Figure 2 shows the performance of the estimated equation. Roughly speaking, the depreciation of the yen in the first half of the 1980's is explained by the widening of interest rate differentials between U.S. and Japan; the rapid depreciation of the yen since the Plaza agreement is explained by an increase in the accumulated current account surplus.

Figure 2
Real yen-dollar rate: actual and fitted
1985 = 100



1.3 Stock price

The stock price equation is based on the idea that the stock price is determined by the present discounted value of future profits. As shown in Table 3, the Nikkei Average is explained by the current profits of all industries and the long-term interest rate. Reflecting the assumption that the expectation of future profits is formed in an adaptive way, the lagged values of profits are included in the right-hand-side of the equation. The parameters associated with the lagged values are estimated by the Shiller lag procedure.

4 The third term of the exchange rate equation is a linear combination of RPJ and RPE. The weight given to RPJ (0.0030) is the variance of the yen/dollar rate; the weight to RPE (0.0017) is the covariance between the yen/dollar rate and the DM/dollar rate. See Fukao (1983, 1987) for more details.

5 Several interesting things can be read from the estimation result. First, the fundamental value is 4.461, which corresponds to the level of the real exchange rate just before the Plaza agreement. Second, the estimated value for μ ($\mu = 1/\alpha_1$ by definition) is 1/2.923. This means that market participants expect the real exchange rate to approach the fundamental value at the rate of 1/2.923 per quarter.

Table 3
Stock price equation

$$\ln(SPI_t) = \alpha_0 + \sum_{j=0}^{2} \alpha_{1_j} \ln(PROF_{t-j}) + \alpha_2 \ln(1/RBND_t)$$

α_0	α_{1j}	α_2	$S.E.$	$\overline{R}^2$	$D.W.$	*Sample*
−3.918	$\alpha_{1,0}$ = 0.838 (9.04)	15.143	0.103	0.92	0.969	84.1
(−5.43)	$\alpha_{1,1}$ = 0.448 (11.18)	(9.36)				94.3
	$\alpha_{1,2}$ = 0.032 (0.40)					
	$\sum \alpha_{1_j}$ = 1.318					

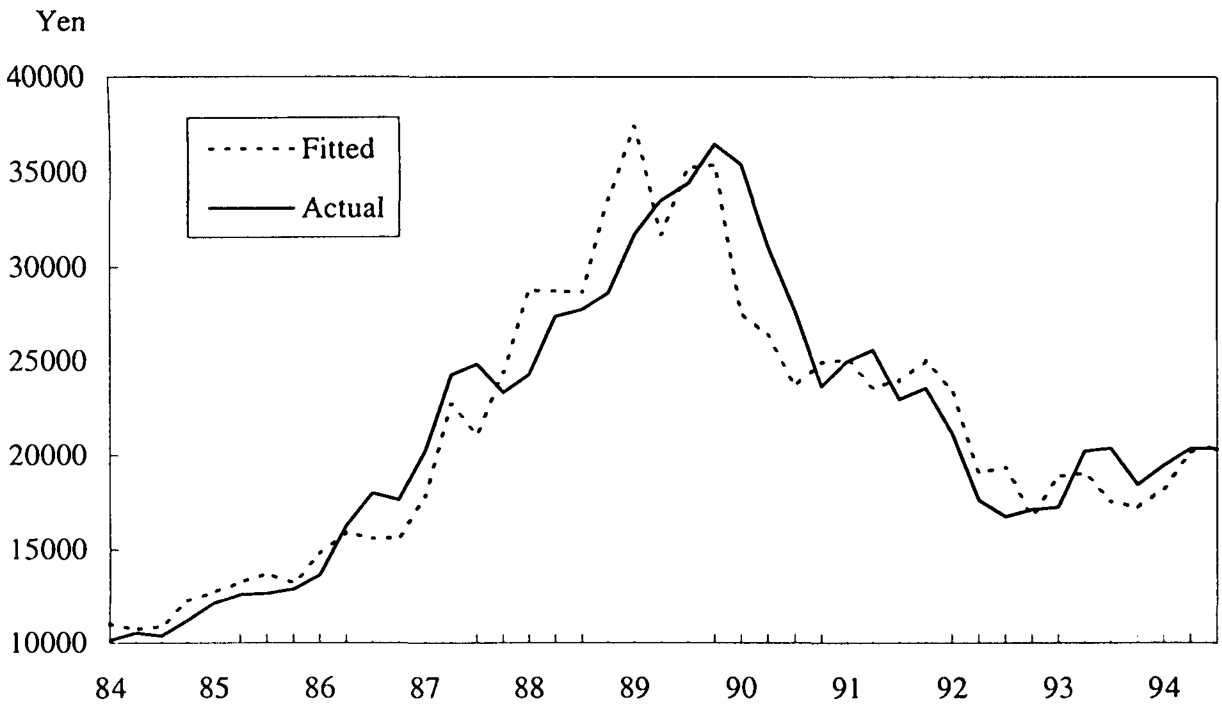
Note: Numbers in parentheses are t-statistics. α_{1j} (j=0,1,2) are estimated by the Shiller lag procedure. *RBND* entered as in Table 1.

SPI Nikkei average, in yen.

PROF Current profits of all industries reported in Financial Statements of Incorporated Businesses, in 100 million yen.

RBND Long-term government bond yield.

Figure 3
Stock prices: actual and fitted



The performance of the stock equation is shown in Figure 3. An interesting thing to note is that almost all fluctuations during the "bubble" period are explained by profits and long-term interest rates. One might say that something must be wrong with the estimation procedure because fluctuations caused by a speculative bubble should not be explained by fundamentals such as profits and interest rates. It is not easy and beyond the scope of this paper, to determine whether fluctuations in stock prices in the late 1980's were due to a speculative bubble or not. But, the estimated result as it is, can be interpreted as follows. As shown in Table 3, the estimated coefficient of current profit is well above one; the sum of α_{1j} equals to 1.318. This means that, when profit increases by 1%, the expectation of future profits increases by 1.318%, thereby pushing up the stock prices by 1.318%. This is how expectations were formed in the Tokyo stock market; one may call this a speculative bubble.

2. Impulse response function of asset prices

2.1 Innovation-simulation technique

The Lucas-critique of conventional simulation analysis might apply to the BOJMOD in which expectations mechanisms are adaptive, or backward-looking as described in the previous section. That is, we cannot rule out the possibility that the parameters of the BOJMOD would shift when a simulation shock is added.

There are two alternative ways to overcome the Lucas-critique. The first one is to modify the BOJMOD by incorporating forward-looking expectations and estimating structural, or deep parameters. The second one is to modify the simulation analysis without changing the structure of the BOJMOD itself. In this section, following the second method, we will study the dynamic response of asset prices to various types of shock.

The methodology we will adopt in this section is the so-called "innovation-simulation technique" proposed by Sargent (1977), Sargent and Sims (1977) and Mishkin (1979). The basic idea of this methodology is as follows.[6] Suppose the structural equations of a macroeconometric model are characterised by:

$$A(L)y_t + B(L)x_t = e_t \tag{6}$$

with y a vector of endogenous variables; x a vector of exogenous variables; e a vector of disturbances and $A(L)$ and $B(L)$ matrices of polynomials in the lag operator L. Also, suppose that the time-series process of the exogenous variables is described by:

$$C(L)x_t = u_t \tag{7}$$

where u is a vector of disturbances. Usually, parameters of $A(L)$, $B(L)$ and $C(L)$ are estimated using a set of historical data.

The standard simulation based on the macroeconometric model computes the deviation of the endogenous variables from the baseline when a shock is added to some of exogenous variables. A problem with this procedure is that when an arbitrary dynamic path of the exogenous variables is chosen for a simulation analysis, there is no guarantee that the path is consistent with equation (7). Put differently, a researcher alter the parameters of $C(L)$ when he chooses an arbitrary path of the exogenous variables. This is a serious problem because the parameters of $A(L)$ and $B(L)$ are not

6 The following explanation is based on Mishkin (1979).

invariant to changes in the parameters of *C(L)*. It is particularly so when the macroeconometric model adopts backward-looking expectations. The moment a researcher chooses an arbitrary path of the exogenous variables, the parameters of *A(L)* and *B(L)* would change; therefore, simulation results based on the estimated parameters could be quite misleading.

A remedy to this problem is to conduct a simulation analysis taking equation (7) into consideration. More specifically, we can generate a dynamic path of the exogenous variables which is consistent with the parameters of *C(L)* by the following procedure: (i) add an innovation to the disturbance term of (7); (ii) compute the dynamic path of the exogenous variables using (7).[7]

The simulation procedure in this section is as follows. First, we estimate an ARIMA model for an exogenous variable (e.g. the short-term money market rate) to which a shock is given. Second, we calculate the dynamic response of the exogenous variable to an innovation. Third, we put the response into the BOJMOD as a dynamic shock. Finally, we calculate the response overtime of the BOJMOD's endogenous variables to the shock.[8]

2.2 Response to an innovation in the call rate

The first experiment is to study the dynamic response of asset prices to an innovation in the call rate. Using the identification procedure based on the AIC, we estimate an ARIMA model of the call rate. As shown in the note to Figure 4, ARIMA(1,0,1) is chosen and estimated over 1982Q1 to 1994Q1 period by the maximum likelihood method.

The upper-left panel shows the dynamic behaviour of the call rate when an innovation of 1 percent is added to the first quarter. It is observed that the call rate goes up further to 1.4 percent in the second quarter because of the existence of a MA term, and then decays gradually over time.

Based on this movement of the call rate, the response of the asset prices is computed using the BOJMOD, which is shown in the other three panels of Figure 4. The first impact of an innovation on the call rate appears on the long-term interest rate.[9] As shown in the upper-right panel, the long-term interest rate jumps up by 0.2 percent in the first quarter and then goes up for three quarters to 0.58 percent, followed by a gradual decay. In response to this, the yen measured by the real yen/dollar rate appreciates 2 percent for the first three years and then gradually returns to the base line: the stock price declines 13 percent for the first two years and returns to the base line.

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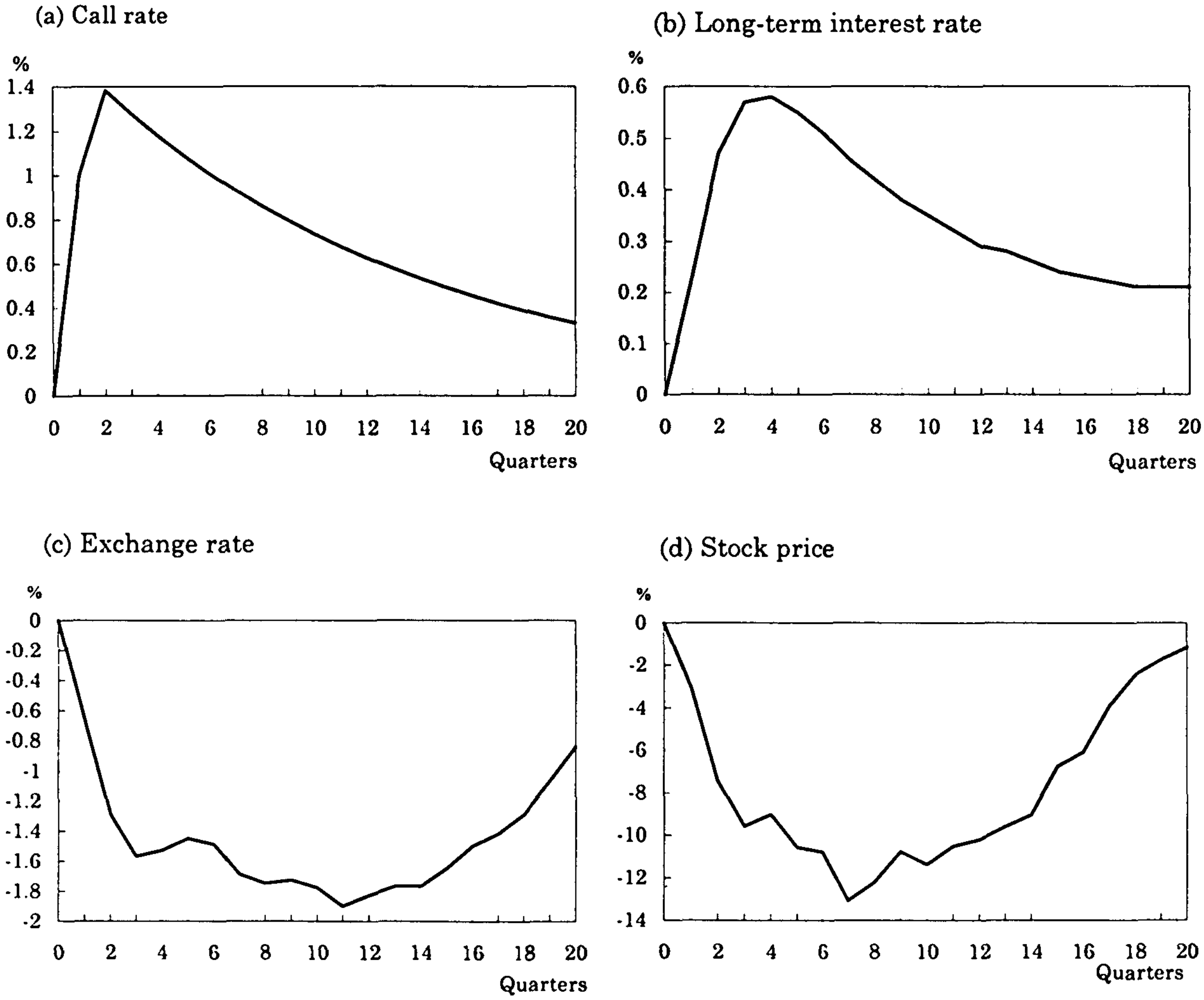
7 In other words, innovation-simulation technique reduces the risk of misleading stimulation results by deliberately specifying the type of simulation shocks that a macroeconometric model with backward-looking expectations is able to handle. This imply a limitation on the innovation-simulation technique: i.e., since the dynamic path of the exogenous variable is specified by the time-series process of the exogenous variables, researchers are not allowed to arbitrarily choose the type of simulation shock. For example, even when a researcher wants to study the impact of a temporary shock for an exogenous variable, he is not allowed to do if the exogenous variable contains stochastic trend.

8 One of the problems in this procedures is that the feedback from the BOJMOD to the ARIMA model is completely ignored. It might be interesting to see how the results of the experiments in this section would change if the interaction between the two models is taken into consideration.

9 In the BOJMOD, a change in the call rate affects the CD rate contemporaneously, and then the long-term interest rate.

Figure 4
Response of asset prices to an innovation in the call rate



Note: Response of asset prices is calculated based on the following ARIMA model of the call rate (*CALL*) estimated over the period 1982Q1 to 1994Q1. Numbers in parentheses are t-statistics.

$$\underset{(-15.48)}{(1-0.924L)}-\underset{(-4.80)}{(CALL_t-5.122)}=\underset{(3.55)}{(1+0.459L)}u_t$$

$$\hat{\sigma}^2=0.29 \qquad \text{AIC}=77.6$$

2.3 Response to an innovation in the current balance/nominal GDP ratio

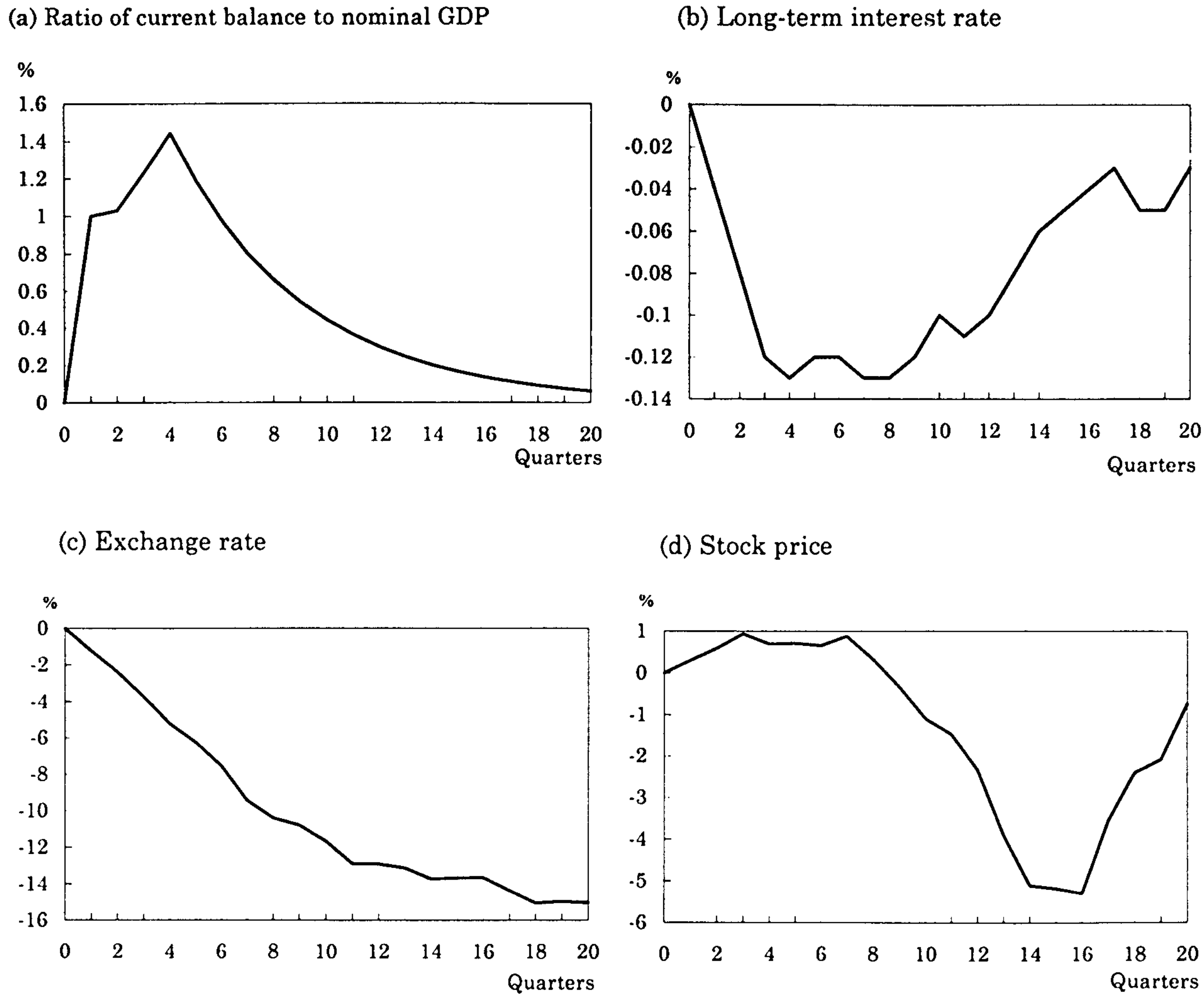
In the BOJMOD, the impact of an innovation in the current account surplus appears on the real side of the economy through net exports and on the monetary side of the economy through the exchange rate. Since the focus of this paper is on the asset price determination, the impact on the real side of the economy is neglected in this experiment.[10]

10 An original shock is given only to the third term of the exchange rate equation. But we do not rule out the possibility that changes in the exchange rate would affect the real side of the economy through net exports.

As shown in the note to Figure 5, the risk premium term of the exchange rate equation, $(0.003RPJ{+}0.002RPE)/IT1$, follows ARIMA(1,1,3). Roughly speaking, this means that the ratio of the current account surplus to nominal GDP follows ARIMA(1,0,3). The dynamic behaviour of the current account surplus/GDP ratio caused by an innovation of 1 percent is depicted in the upper-left panel. The ratio increases during the first four quarters up to 1.4 percent and then decays rapidly.

Figure 5

Response of asset prices to an innovation in the ratio of the current balance to nominal GDP



Note: Response of asset prices is calculated based on the following ARIMA model of the ratio of accumulated current balance to nominal GDP estimated over the period 1975Q2 to 1994Q4. Numbers in parentheses are t-statistics.

$$\underset{(-11.38)}{(1-0.821L)}\left((1-L)\left((0.003RPJ_t+0.002RPE_t)/IT1\right)-\underset{(-1.43)}{0.005}\right)=\left(1+\underset{(1.89)}{0.210L}+\underset{(3.89)}{0.385L^2}+\underset{(4.06)}{0.432L^3}\right)u_t$$

$$\hat{\sigma}^2=0.00001 \qquad \mathrm{AIC}=666.4$$

RPJ Cumulative current account surplus of Japan minus direct investments, in millions of dollars and starting in 1974Q1.

RPE Cumulative current account surplus minus direct investments of Germany, France, Italy and the Netherlands, in millions of dollars and starting in 1974Q1.

*IT*1 Index of nominal GDP of Japan, the United States, Germany, France, Italy and the United Kingdom, 1975Q1=100.

Since the risk premium is a function of the ratio of the cumulative current balance to nominal GDP, what governs the behaviour of the exchange rate is the integral of the deviation of the current account/nominal GDP ratio from the base line, which monotonically increases with time. As shown in the lower-left panel, the exchange rate gradually appreciates during the first 18 months and then stabilises.

In response to this, the long-term interest rate first goes down and then returns to the base line. Meanwhile, the stock price goes up slightly during the first seven quarters responding to lower long-term interest rates. In the eighth quarter it starts to decline, reflecting the deterioration of corporate profits caused by the appreciation of the yen.

2.4 Response to an innovation in the budget deficit to nominal GDP ratio

The impact of an innovation in the budget deficit appears on the real side of the economy through the government's net saving and on the monetary side of the economy through the long-term interest rate. As in the previous experiment, the impact on the real side of the economy is neglected in this experiment.

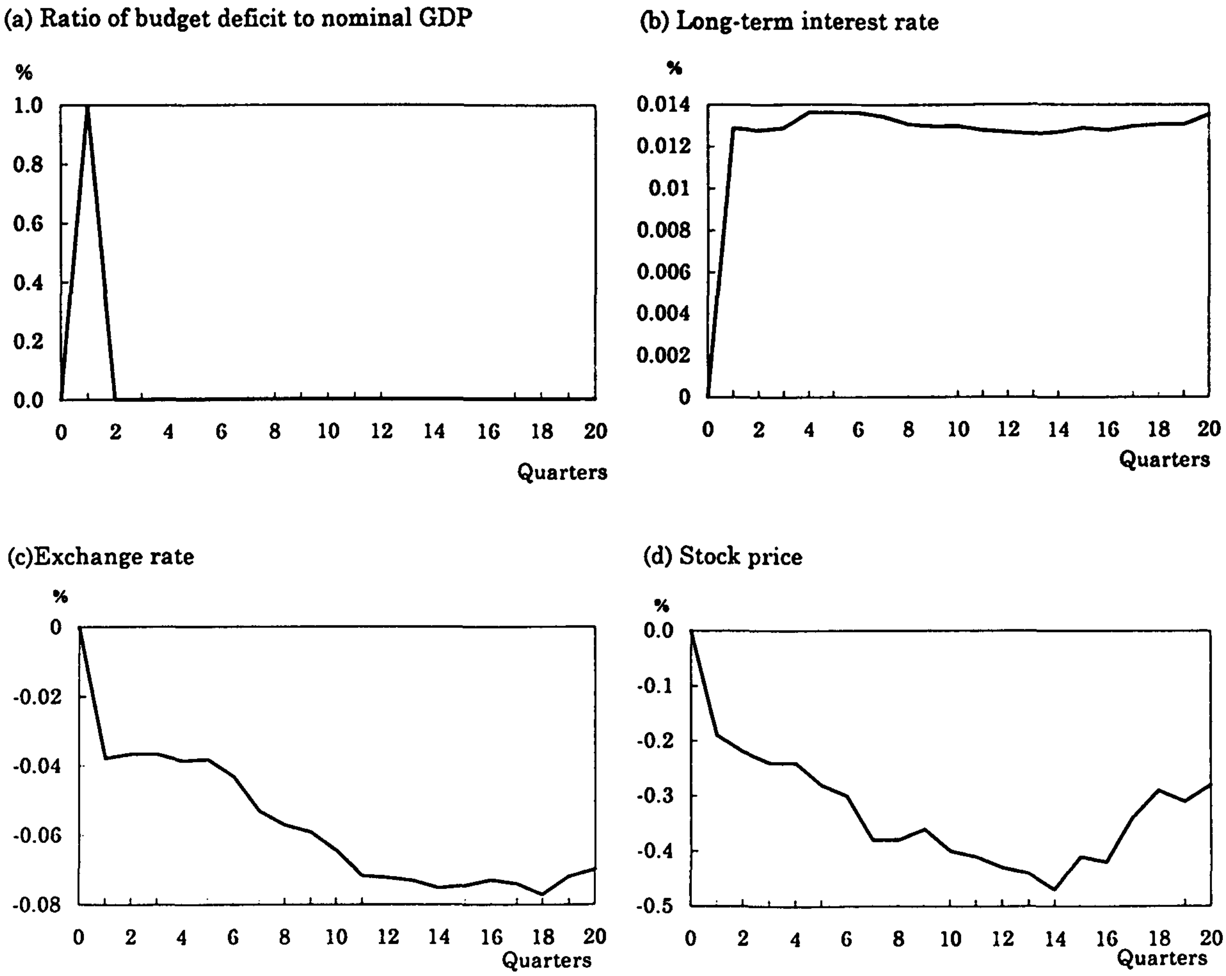
As shown in the note to Figure 6, the government debt to nominal GDP ratio follows ARIMA(0,1,1). Combined with the finding that the estimated parameter of the MA1 term almost equals unity (0.9998), this means that the ratio of government debt to nominal GDP is characterised by a white noise process with a deterministic trend.[11] The dynamic behaviour of the budget deficit to nominal GDP ratio, which is depicted in the upper-left panel, indicates that the shock is transitory in the sense that it has no effects in and after the second quarter.

The response of the long-term interest rate, which is depicted in the upper-right panel, shows that the long-term rate jumps up immediately in the first quarter and then stabilises. Responding to this, both the exchange rate and the stock price show a discrete jump in the first quarter and a gradual change in the subsequent quarters.

11 As shown in the note to Figure 6, the ratio of government debt to nominal GDP ratio has a deterministic trend which decreases at the rate of 0.22 percent per quarter.

Figure 6

Response of asset prices to an innovation in the ratio of the budget deficit to nominal GDP



Note: Response of asset prices is calculated based on the following ARIMA model of the ratio of accumulated budget deficit to nominal GDP estimated over the period 1980Q1 to 1989Q4. Numbers in parentheses are t-statistics.

$$\underset{}{(1-L)(GDS_t/GDPN_t)} + \underset{(27.36)}{0.0022} = (1-\underset{(-15.15)}{0.9998}L)_{u_t}$$

$$\hat{\sigma}^2 = 0.00003 \quad \text{AIC} = 281.8$$

GDS/GDPN Ratio of the accumulated budget deficit to nominal GDP.

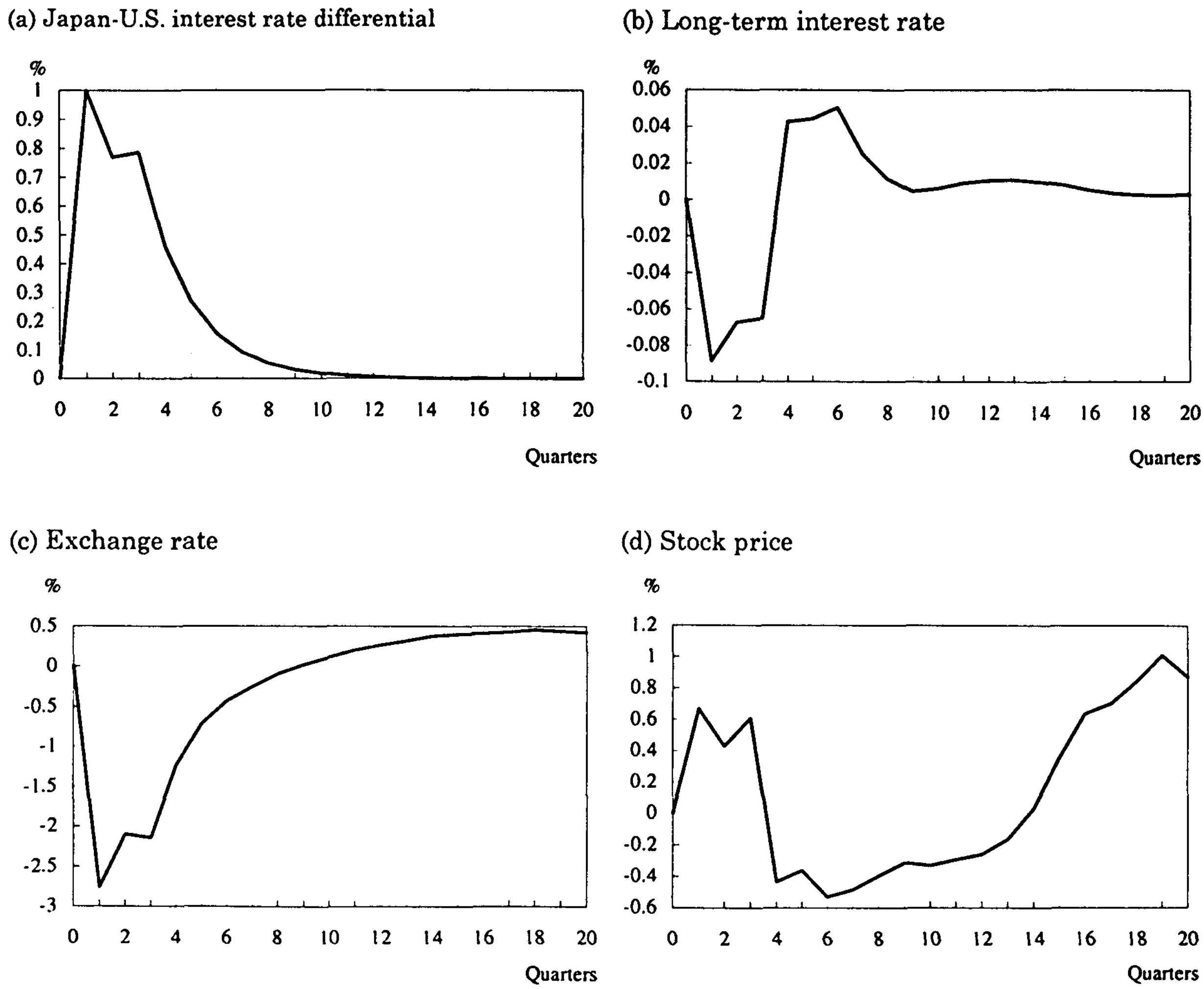
2.5 Response to an innovation in the Japan-US interest rate differential

The final experiment is to study the dynamic response of asset prices to an innovation in the Japan-US interest rate differential. As shown in the note to Figure 7, the interest rate differential follows the ARIMA(1,0,2) process. When an innovation of 1 percent is added to the process, the interest rate differential reaches a peak in the first quarter and then quickly decays (see the upper-left panel).

This dynamic shock affects first the exchange rate. As shown in the lower-left panel, the yen/dollar rate appreciates 2.7 percent in the first quarter and then returns to the base line. This leads to a discrete decline in the long-term interest rate and subsequently to a discrete rise in the stock price.

Figure 7

Response of asset prices to an innovation in the Japan-US interest rate differential



Note: Response of asset prices is calculated based on the following ARIMA model of the Japan-US interest rate differential estimated over the period 1981Q1 to 1995Q2. Numbers in parentheses are t-statistics.

$$(1-0.587L)((RBNDR_t - USBNDR\,10_t)/100+0.630) = (1+0.183L+0.334L^2)u_t$$

(-3.64) (1.99) (1.99) (2.22)

$$\hat{\sigma}^2 = 0.46 \qquad \text{AIC} = 130.1$$

RBNDR Japanese real long-term interest rate. Defined as the Japanese government bond yield minus the annual growth rate of the Japanese GDP deflator.

USBNDR10 US real long-term interest rate. Defined as the US government bond yield minus the annual growth rate of the US GDP deflator.

3. Backward-looking versus forward-looking expectations

The experiment we will conduct in this section is to compute the responses of asset prices to the same shock as in Section 2 but under the assumption of forward-looking expectations and to compare them with those obtained in Section 2.

Among the simulations, we have chosen two experiments: (i) the response of long-term interest rate to an innovation in the call rate; (ii) the response of the yen/dollar rate to an innovation in the Japan-US interest rate differential.[12]

3.1 Response of the long-term interest rate to an innovation in the call rate

To compute the response of the long-term interest rate to an innovation in the call rate under the assumption of forward-looking expectations, suppose market participants have the estimated time-series model for the call rate. That is, market participants know that the call rate follows ARIMA(1,0,1) and have the estimated parameters shown in the note to Figure 4. Based on this knowledge, they are able to compute the dynamic behaviour of the call rate depicted in the upper-left panel. Those future values of the call rate are put into equation (1) to calculate the long-term interest rate in each quarter.[13] Panel (c) of Figure 8 depicts the response of the long-term interest rate computed in this way.

Comparing panel (c) with panel (a), we find the following. First, the shape of response functions looks similar: a quick response to the shock and then a gradual decay.

Second, the magnitude of the response is almost the same: the peak of the response is 0.5 to 0.6 percent and the response in the 20th quarter is 0.1 to 0.2 percent. These similarities could be interpreted as additional evidence that the simulation in Section 3 based on innovation-simulation technique has not yielded misleading results. This point becomes clearer when we compare the above results with panel (b) which shows the result obtained when a sustained shock of 1 percent is added to the call rate (this case is called "standard simulation technique"). One of the differences between panels (b) and (a) as well as (c) is that the long-term interest rate continues to rise over the 20 quarters. This seems to be an inevitable consequence of the two assumptions: (i) expectations are backward-looking; (ii) shocks are permanent. But the problem here is that the combination of the two assumptions is not realistic in the following sense. If market participants are in some sense rational, they will, at some point, recognise that the shock is permanent and will stop using the mechanical backward-looking expectation process. At the moment market participants start to expect the future short rates on a forward-looking basis, the long-term interest rate would show a discrete jump. In this sense the result obtained by "standard simulation technique" is misleading.

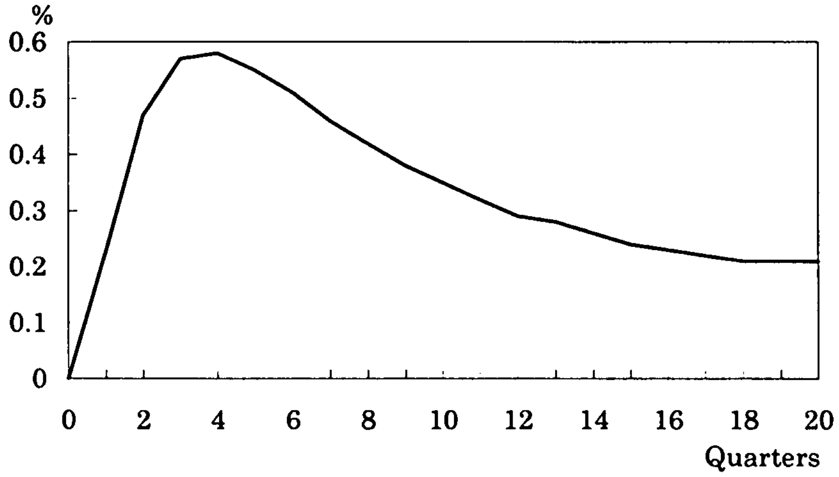
The third thing we should note is the speed at which the long-term interest rate rises in response to an innovation in the call rate. In panel (c), the reaction takes place immediately: the long-term interest rate jumps up in the first quarter and starts to decay in the second quarter. This is consistent with the market efficiency hypothesis. On the other hand, it takes 4 quarters to reach the peak in panel (a). Obviously, this is not consistent with the market efficiency hypothesis but the length of 4 quarters could be justified as the time required for market participants to recognise that the shock is a permanent one. Given the absence of empirical evidence on the speed of learning, it is next to impossible to say which one is a right reaction to the shock.

12 The reason for choosing these two experiment is that simulation results under the assumption of backward expectations are easy to compute. See footnote 14 for the evaluation of other experiments.

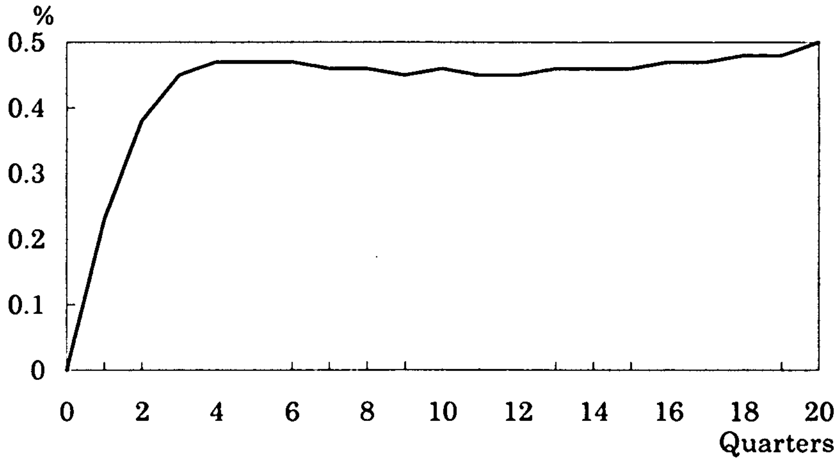
13 β is set at 0.97 (the discount rate is 3 percent).

Figure 8
Backward-looking versus forward-looking:
response of the long-term interest rate to an innovation in the call rate

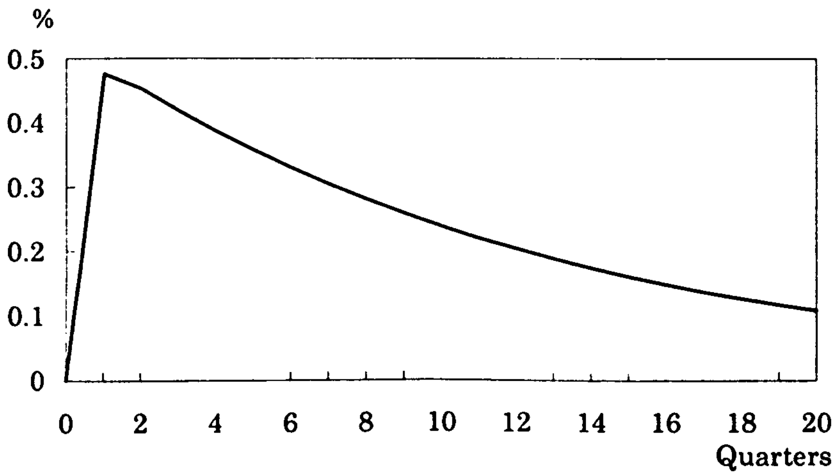
(a) innovation-simulation technique



(b) standard simulation technique



(c) forward-looking expectations



Note : See the text for details on the calculation of impulse response functions.

3.2 Response of the yen/dollar rate to an innovation in the interest rate differential

The response of the yen/dollar rate to an innovation in the interest rate differential under the assumption of forward-looking expectations is computed as follows. First, it is assumed that market participants have the estimated time-series model for the interest rate differential; i.e. they know that the interest rate differential follows ARIMA(1,0,2) and have the estimated value shown in the note to Figure 7. Based on this knowledge, they are able to compute the dynamic behaviour of the interest rate differential plotted in the upper-left panel.

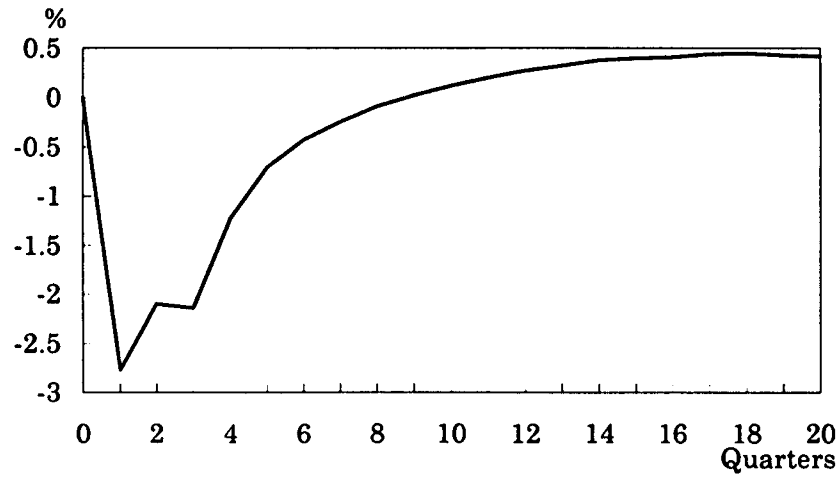
The next thing we should do is to compute the expectation of the real exchange rate, $E_t(q_{t+1})$ of equation (3), without relying on equation (4). As equation (3) indicates, we need q_{t+1} to compute q_t, and q_{t+2} to compute q_{t+1} and so on; therefore, in principle, we have to know q_∞ to compute q_1. But the convenient fact in this experiment is that since the interest rate differential reaches zero on the 14th quarter and stays zero in the subsequent quarters, the exchange rate is also zero on and after the 14th quarter. This means that the expectation of the real exchange rate for the 14th quarter formed on the 13th quarter, $E_{13}(q_{14})$, is zero. Since we know $E_{13}(q_{14})$ and $r_{13} - r_{13}*$, we can now compute q_{13}. Applying the same backward-induction methodology, we can compute q_{12}, q_{11}, q_{10}, ..., and finally q_1. Panel (c) of Figure 9 shows the response of the yen/dollar rate computed in this way.

A casual comparison between panels (c) and (a) reveals the following. First, the shape of response functions is surprisingly similar: both panels show a discrete jump in the first quarter and decays in and after the second quarter. A minor difference is that panel (a) shows a slight appreciation of the yen from the second to the third quarter while panel (c) shows a consistent depreciation in and after the second quarter. Second, the magnitude of the response is almost the same: the peak of the response is 3 to 4 percent. Again, these two findings could be interpreted as evidence that the combination of the BOJMOD and innovation-simulation technique works well. Meanwhile, panel (b) which plots the response obtained when a sustained shock of 1 percent is added to the interest rate differential seems to show another misleading result.[14]

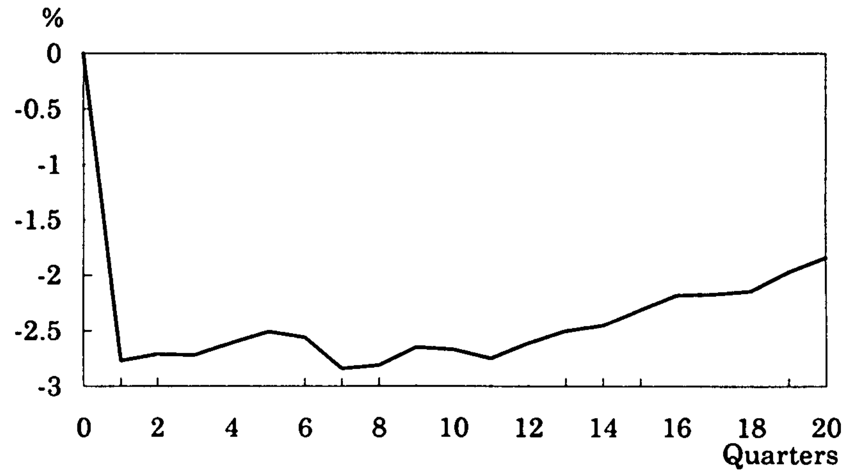
14 In this section, we have evaluated the results of the two experiments conducted in Section 2 by comparing them with the results obtained under the assumption of forward looking expectations. Let us briefly evaluate the remaining two experiments based on the responding speed of asset prices to shocks. Responses of the exchange rate to an innovation in the current balance to nominal GDP ratio is very slow and it is not until the 18th quarter that the exchange rate starts to stabilise (Figure 5). This is not a reasonable response of market participants: if they are in some sense rational, the exchange rate should show a discrete jump. As for the response of the long-term interest rate to an innovation in the budget deficit to nominal GDP ratio (see Figure 6, the computed response is quick so that the result is consistent with the hypothesis of efficient markets.

Figure 9
Backward-looking versus forward-looking:
response of the yen/dollar rate to an innovation in the Japan-US interest rate differential

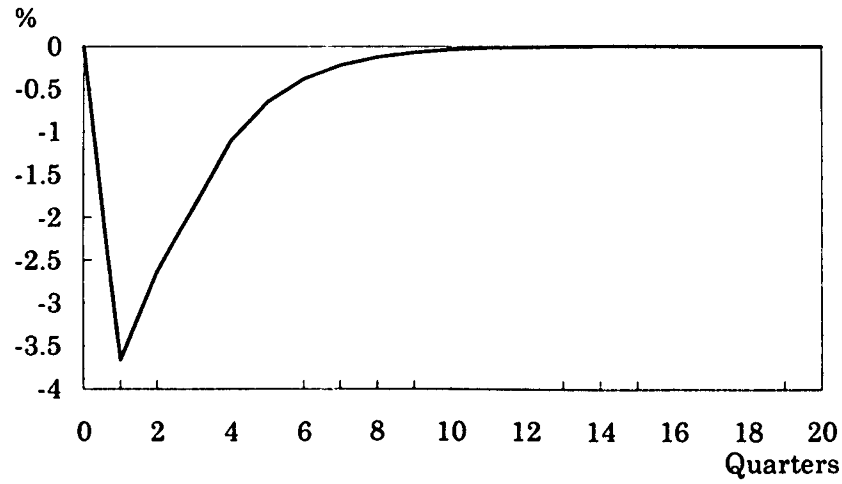
(a) innovation-simulation technique



(b) standard simulation technique



(c) forward-looking expectations



Note : See the text for details on the calculation of impulse response functions.

Conclusion

The asset price equations of the BOJMOD adopt backward-looking expectations. As Lucas pointed out in his celebrated paper in 1976, simulation analysis using this type of macroeconometric model could yield misleading results because parameters would shift when a shock is added. There are two alternative ways to overcome the Lucas-critique. The first is to modify the BOJMOD by incorporating forward-looking expectations and estimating structural, or deep parameters; the second is to modify the way simulation analysis is conducted without changing the structure of the BOJMOD itself. In this paper we have chosen the second way to study the dynamic response of asset prices to various types of shock.[15]

The methodology we have adopted in this paper is the so-called "innovation-simulation technique" proposed by Sargent, Sims and Mishkin. The basic idea of this methodology is straightforward: (i) the parameters of conventional macroeconometric models are not independent of the process generating an exogenous variable to which a simulation shock is added; (ii) the reason for the shift of parameters is that conventional simulation methodology gives a shock to the model which is not consistent with the process generating the exogenous variable; (iii) therefore, if we add a shock consistent with the process generating the exogenous variable, parameters will not shift.

Using this methodology, we have computed the dynamic responses of asset prices to various types of shock to find that: (i) the responses of asset prices, overall, do not contradict the hypothesis of efficient markets; (ii) the responses of asset prices computed in this way are very similar to those computed under the assumption of forward-looking expectations.

Overall, our experiments show that the innovation-simulation technique is a useful tool to study the dynamic property of conventional macroeconometric models like the BOJMOD.

15 The innovation-simulation technique is a useful tool but has some limitations. For example, when we want to study the consequences of unprecedented policy changes, this technique will not work. All that we can do by this technique is to study the impact of various shocks which have taken place more than several times in the past. If we really want to know the effect of unprecedented shocks, we need to estimate structural parameters.

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Comments on paper by T. Watanabe and H. Matsuura by R. McCauley (BIS)

This very useful paper points to a puzzle regarding the power of monetary policy over the bond market in Japan; raises a question regarding how to operationalise a portfolio-balance model; and perhaps sounds a warning that a fundamental model should not perform too well in the presence of asset inflation and deflation.

1. Long-term interest rates

The estimated equation says that the long-term interest rate is firmly tied to short-term bank rates in the current and previous quarter, to the government debt, to a combination of the US bond yield, Japanese and US inflation, and to the exchange rate, all with expected signs.

The first question is which Japanese long-term government bond yield is being explained, since the Japanese bond market shows an extremely strong benchmark effect. In particular, the benchmark bond can trade as much as 50 basis points away from adjoining non-benchmark bonds at times like mid-1987, and its yield volatility is much higher than nonbenchmark bonds of much shorter maturity.

The very close relation of short-term to long-term interest rates may be related to the long-term puzzle of why, over the cycle, Japan's money and bond markets show one of the flattest yield curves in the world. Of course, this question may seem beside the point at a time when the Japanese yield curve is quite steep. One way of putting the question is why does Bank of Japan policy have such a large and fast effect on long-term interest rates? As Inoue, Ishida and Shirakawa put it with considerable understatement at the Autumn Economists' meeting here last month, "[bond market] investors are quite sensitive to the expected future course of short-term rates."

Would the equation perform better if it included money market rates a little less tied to current overnight rates and rather more indicative of future overnight rates? Including forward money market rates from Euroyen futures or implied in the structure of cash bank deposit rates, one could test for whether the an appreciation of the yen works directly to lower the expected price level and thereby to lower bond yields, or whether it works indirectly through market participants' expectations of easier Bank of Japan policy. Moreover, one wonders whether the use of a CD rate as the representative short-term rate - which is quite an understandable choice - yields forecasting errors when, as now, a gap opens between Treasury bills and Japanese bank rates (which is related to the so-called Japan premium).

This reader did not understand why US long rates, Japanese and US inflation are all combined into one variable. The variable seems to be based on the notion that investors compare real yields on Treasuries against real yields on JGBs. This investment strategy makes sense in a world in which the yen-dollar exchange rate moves to offset inflation differentials. It is hard to imagine that the wild swings in the purchasing power of the yen in relation to the dollar have left many investors inclined to bet on real yield differentials.

The fiscal factor seems to neglect the ownership of the debt. One wonders whether various government trust-fund purchases/holdings of government bonds should be excluded. At high frequencies, at least, the market seems to react to reports that a trust fund is to buy or to sell government bonds.

2. Yen-dollar exchange rate

The model relates the real yen-dollar exchange rate to the difference between real long-term interest rates in Japan and the US and to the accumulated current account surplus of Japan and Europe, weighted more or less 2 to 1. Again, given the large swings in purchasing power parity, and all the evidence of a persistent gap between the internal and external value of the yen, it is strange to start with the notion that the market is itching to get back to a fundamental purchasing power rate and is temporarily dragged away by first interest rate differentials and then by an accumulating international asset position.

The inclusion of Japan's net asset position is fairly common in models of the yen-dollar exchange rate but this model distinguishes itself in excluding direct investment. Whether direct investment into Japan is excluded does not much matter empirically, but the rationale - that direct investment is "irrelevant to the risk premium" - would bear elaboration.

More importantly, the same rationale might well require an exclusion of the build-up of Bank of Japan reserves, and perhaps also the foreign assets of the postal life insurance system, Japan ExIm and other such government holdings. When, as in 1995, the accumulation of foreign assets by the Bank of Japan and others recycles the bulk of the current account surplus, this alternative measure would grow much more slowly than the accumulated current account balance. Although there has been some public discussion in Japan of the accumulated losses on official dollar holdings, it is hard to believe that private investors see through the government balance sheet and perceive as their own the exchange risk on official holdings of dollars. Would the exchange rate really remain unaffected by the Japanese authorities' liquidating their international reserves?

3. Equity prices

The model relates the log of the level of the Nikkei average to the log of corporate earnings and to the log of the inverse of the long-term government bond yield. At an econometricians' meeting, one can expect the comments to focus on whether the regression in levels with lags should be expected to produce reliable results. Instead, consider the choice of variables and sample period.

If the stock market discounts future earnings, one can relate the capitalisation to total earnings of listed companies or a share price index to earnings per share. The model relates the index to total profits, an acceptable approximation if share issuance were negligible. In fact, in the late 1980s Japanese corporations issued new shares into a booming market, so that total profits grew significantly faster than earnings per share. If earnings per share were used the coefficients on corporate earnings would be still higher.

The response of share prices to corporate earnings is very strong, a case of Hicksian elastic expectations. As it stands the sample period seems almost designed to model the bubble in share prices. Did Japanese share prices show such elasticity to earnings before 1985? Or would an equation estimated over an earlier period have shown share prices cutting loose from fundamentals in the mid- to late-1980s?

The answer to the question regarding the pre-sample performance of the equity equation is of more than econometric interest. As head of the Economic Planning Agency, Yoshitomi could specify the year in which the agency's land price equation broke down. One of the reasons for maintaining a central bank model for an important asset price is to inform judgements of whether the price has lost contact with the fundamentals, that is, to provide an early warning. Chart 11 in the Inoue, Ishida and Shirakawa paper tells the tale: a reasonable present value calculation shows that the Nikkei lost touch with the underlying earnings growth in the late 1980s.